## Indra: An Agent-Based Modeling System

### What Is a Model?

1. Models are constructed.  
   2) They are made of distinct parts. (E.g., "a supply curve, a demand curve, an x-axis, a y-axis," or "red lines for highways, black lines for local roads, dashed lines for dirt roads.")  
   3) The parts are made to fit together. (The supply curve is measured in the same units as the demand curve, and crosses it somewhere. The roads are laid out on the same grid, using the same scale.)  
   4) We can adjust those parts, either purely mentally, or with our hands (as with an architectural model), or a pencil and eraser (a mechanical drawing), a computer (a weather model), and so on. (In using a map, we actually adjust a "part" we will in: where we are. Sometimes, this part is represented by our finger, as we trace a route, or the mark of a highlighter.)  
   5) Adjusting the parts produces an "answer" of some sort from the model: "Oh-oh, if we move that wall there, the stairs won't fit," or "If the supply curve shifts that far right, the new price will be $4.50."  
   6) The modeler hopes that the answer produced by the model says something about what will happen when changes occur in (or are deliberately made to) the thing being modeled.

“One such use — the simplest — is conceptually quite close to traditional simulation in operations research. This use arises when equations can be formulated that completely describe a social process, and these equations are explicitly soluble, either analytically or numerically. In the former case, the agent model is merely a tool for presenting results, while in the latter it is a novel kind of Monte Carlo analysis. A second, more commonplace usage of computational agent models arises when mathematical models can be written down but not completely solved. In this case the agent-based model can shed significant light on the solution structure, illustrate dynamical properties of the model, serve to test the dependence of results on parameters and assumptions, and be a source of counter-examples. Finally, there are important classes of problems for which writing down equations is not a useful activity. In such circumstances, resort to agent-based computational models may be the only way available to explore such processes systematically, and constitute a third distinct usage of such models.” (Axtell, 2000)

### How Indra Is Constructed

#### Object-oriented programming and agent models

#### Whitehead’s process philosophy

### Our Models

#### Schelling’s Height Model

Schelling (2006) asks what will happen if the genetic engineering of humans advances to the point where we can control the height of our children, and further, that what people generally desire is merely that their own offspring not be “runts”: perhaps, no one wants their child to be in the bottom 10% of heights in the population, recalling how the “runts” got picked on in school.

Schelling notes that since a population *must* have a bottom 10%, it is not possible for everyone at once to ensure that their children are not in the decile. Instead, what will occur is that the effort to see that that is so will result in a increasing average height for humans, a result intended by no one.

Our modeling here shows that Schelling’s intuition can be easily formalized in an ABM.

#### Krugman’s Baby-Sitting Co-op

#### Schelling’s Segregation Model

As Thomas Schelling famously pointed out, it is not necessary for all or even most individuals to want to live in a largely segregated neighborhood for such neighborhoods to arise: all that is needed is for most people not to want to be “too small” a minority in their neighborhood.

#### A Predator-Prey Model

#### Adam Smith’s Fashion Model

“Fashion is different from custom, or rather is a particular species of it. That is not the fashion which every body wears, but which those wear who are of a high rank, or character. The graceful, the easy, and commanding manners of the great, joined to the usual richness and magnificence of their dress, give a grace to the very form which they happen to bestow upon it. As long as they continue to use this form, it is connected in our imaginations with the idea of something that is genteel and magnificent, and though in itself it should be indifferent, it seems, on account of this relation, to have something about it that is genteel and magnificent too. As soon as they drop it, it loses all the grace, which it had appeared to possess before, and being now used only by the inferior ranks of people, seems to have something of their meanness and awkwardness.” (Smith, 2015)

#### Edgeworth Box Model

A major concern here was to keep the model “realistic,” in the sense that we did not want our agents to be able to peer inside other agents endowments or utility functions. An agent proposing a trade had to do so blindly, without any knowledge of whether the other agent had any interest in a good at all.

#### Barter Model

Next, we added multiple agents to our Edgeworth Box model. All of the “negotiating” code from the Edgeworth Box model was inherited in this model, and so we found this model relatively trivial to decode.

#### Menger Model

Finally, in our Menger model, we are attempting to see money arise from a good gaining increasing acceptance as a medium of exchange. This model is, so far, interesting as an instance of a spectacular failure of our intentions, and a refutation of the idea that a researcher can merely set up an ABM to get whatever outcome they want. In creating the model, the intention was to have gold emerge as the medium of exchange, by first making it the most durable good, and then by adding to the utility of any good whenever someone will accept it in exchange.

What happened with our first attempt was a dramatic illustration of the fact that, when done properly, these models are vehicles for experimentation, and not simply ways to get out of a computer what you put into it: we thought we had given gold durability and utility characteristics that would make it emerge as money. Instead, what happened was that gold treated in the first round of agent interaction, and then never traded again! In fact, we had created a sort of anti-money that would *never* circulate.

The “interesting result” was eventually fixed so that gold did emerge as money. However, it took extensive experimentation with the model to see what had been done “wrong” in the first place. (The chief thing was the gold had been given too low a marginal utility for the first unit an agent would gain or lose.)

### Conclusion

The Indra system has now been developed to the point that it is relatively easy to generate interesting models using the framework it provides. To advance its development, the main thing it needs now is more users.

### References

Axtell, Robert. 2015. “Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences.” *The Brookings Institution*. Accessed March 15. http://www.brookings.edu/research/reports/2000/11/technology-axtell.

Callahan, Gene, and Andreas Hoffmann. 2015. *Two-Population Social Cycle Theories*. SSRN Scholarly Paper ID 2560270. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2560270.

Downey, Allen. 2012. *Think Complexity*. Sebastopol, Calif.: O’Reilly.

Krugman, Paul. 1998. “Baby-Sitting the Economy.” *Slate*, August 14. http://www.slate.com/articles/business/the\_dismal\_science/1998/08/babysitting\_the\_economy.html.

Menger, Carl. 2015. “On the Origin of Money,” Accessed March 15. http://www.monadnock.net/menger/money.html.

Morgan, Mary S. 2012. *The World in the Model: How Economists Work and Think*. Cambridge; New York: Cambridge University Press.

Schelling, Thomas C. 2006. *Micromotives and Macrobehavior*. New York: Norton.

Smith, Adam. 2015. *Theory of Moral Sentiments*, Part V. Of the Influence of Custom and Fashion | Library of Economics and Liberty.” 2015. Accessed March 15. http://www.econlib.org/library/Smith/smMS5.html.